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Bird et al.

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[54] **PORTABLE 90 DEGREE PROOF LOADING DEVICE**

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[73] Assignee: **The United States of America as represented by the Administrator of the National Aeronautics & Space Administration,** Washington, D.C.

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[51] **Int. Cl.**[4] **G01L 5/00**

[52] **U.S. Cl.** **73/862.54;** 73/862.01

[58] **Field of Search** 73/761, 862.01, 862.23, 73/862.49, 862.54, 862.58, 825

[56] **References Cited**

U.S. PATENT DOCUMENTS

3,485,092	12/1969	Benner	73/862.53
3,563,087	2/1971	Brunelle et al.	73/761
3,693,418	9/1972	Kaspareck	73/862.01
4,030,353	6/1977	Shutt	73/862.23

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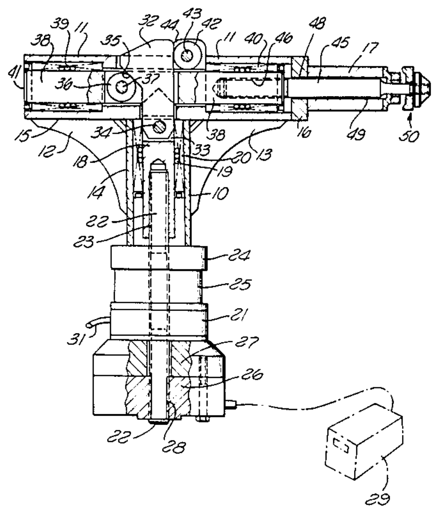
[57] **ABSTRACT**

A hydraulically actuated device for applying a test load to a bearing or the like to prove the integrity of its mounting or staking within a bore in a housing such as a gear case or the like. To accommodate limited access situations the device is constructed in a right angle configuration in which a hydraulic cylinder **21** applies axial pressure to a first thrust rod assembly which includes first thrust rod **18** through threaded spindle **22** driving a linearly translated cam **32** engaging a cam follower wheel **36** to transfer the translation to a second thrust rod assembly which includes a horizontal shaft **38** and spindle **45** within a cross-arm housing portion **11** and a tubular housing portion **17.** The same second thrust direction applies the bearing loading in either of two directions depending upon the shape of the interface parts comprising interface part **57,** washer **58,** and interface part **60** at the extremities of the spindle **45** and its tubular housing portion **17.** The interface parts can bear on the bearing under test from either side thereof with respect to the bearing mounting structural part **51.**

14 Claims, 5 Drawing Figures



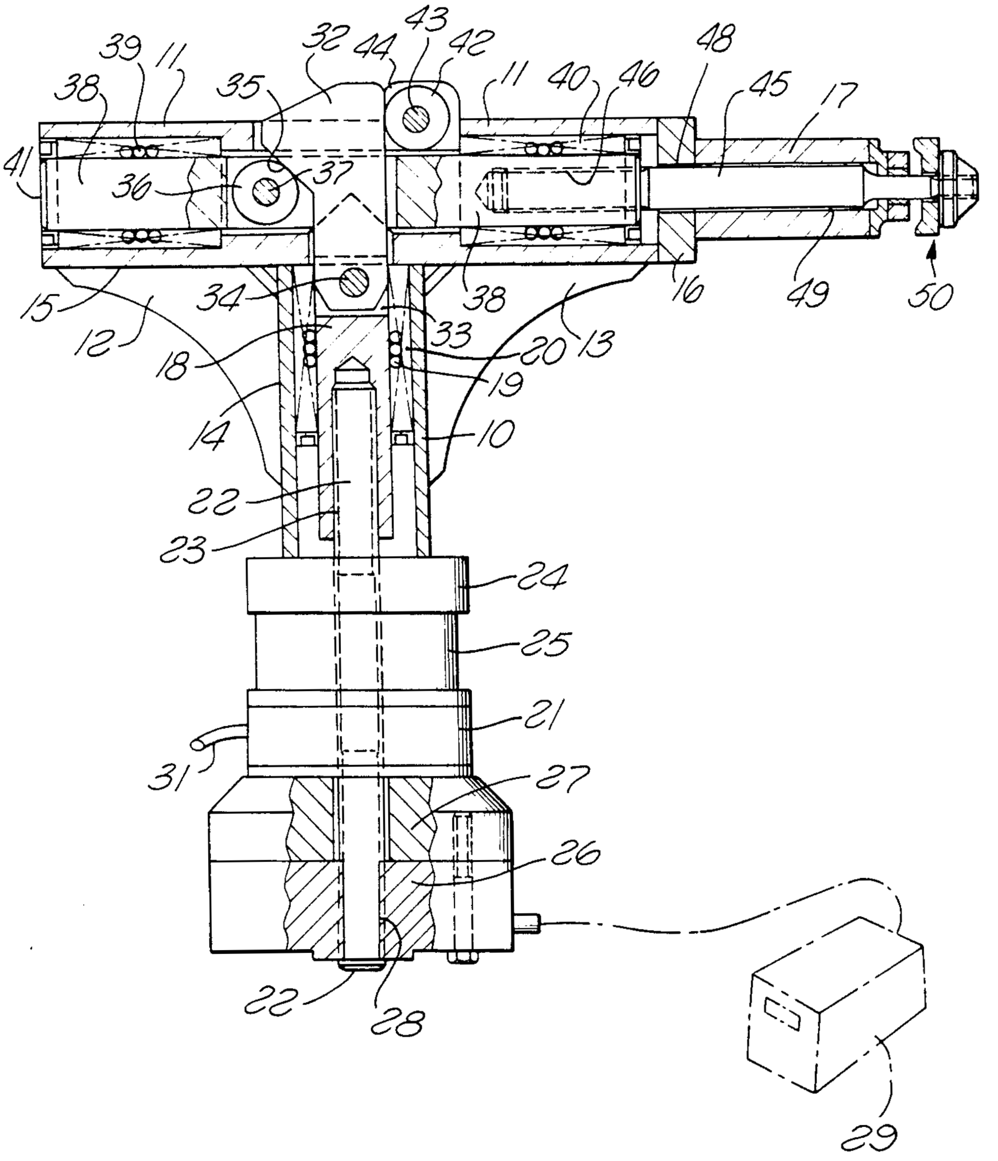

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FIG. 1

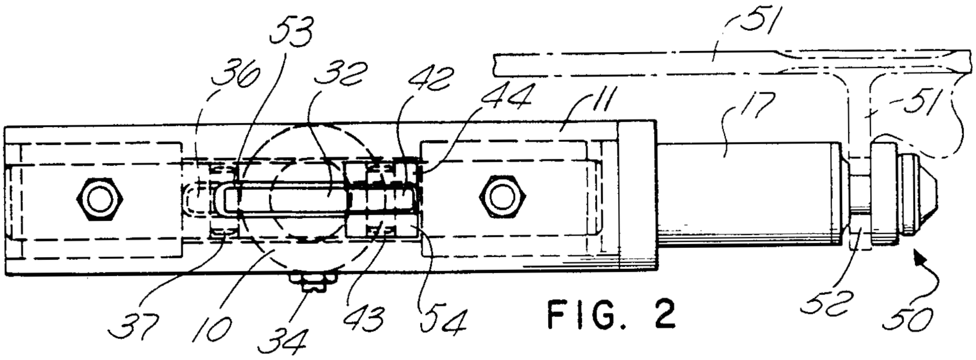

FIG. 2

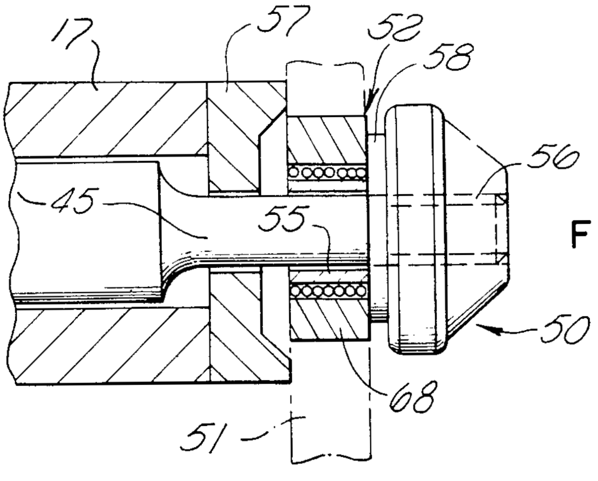

FIG. 3a

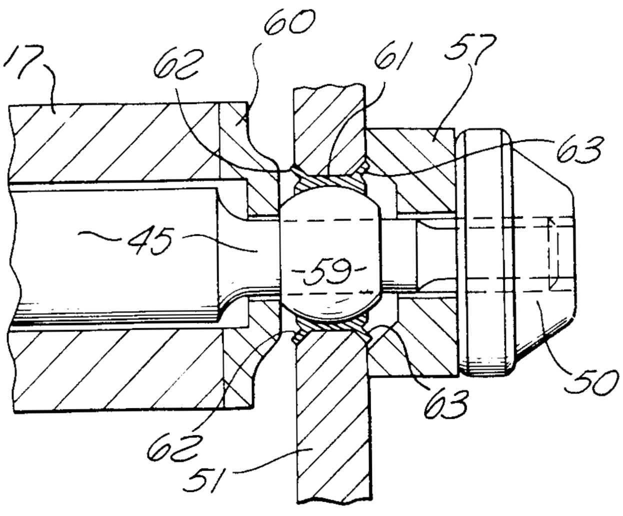

FIG. 3b

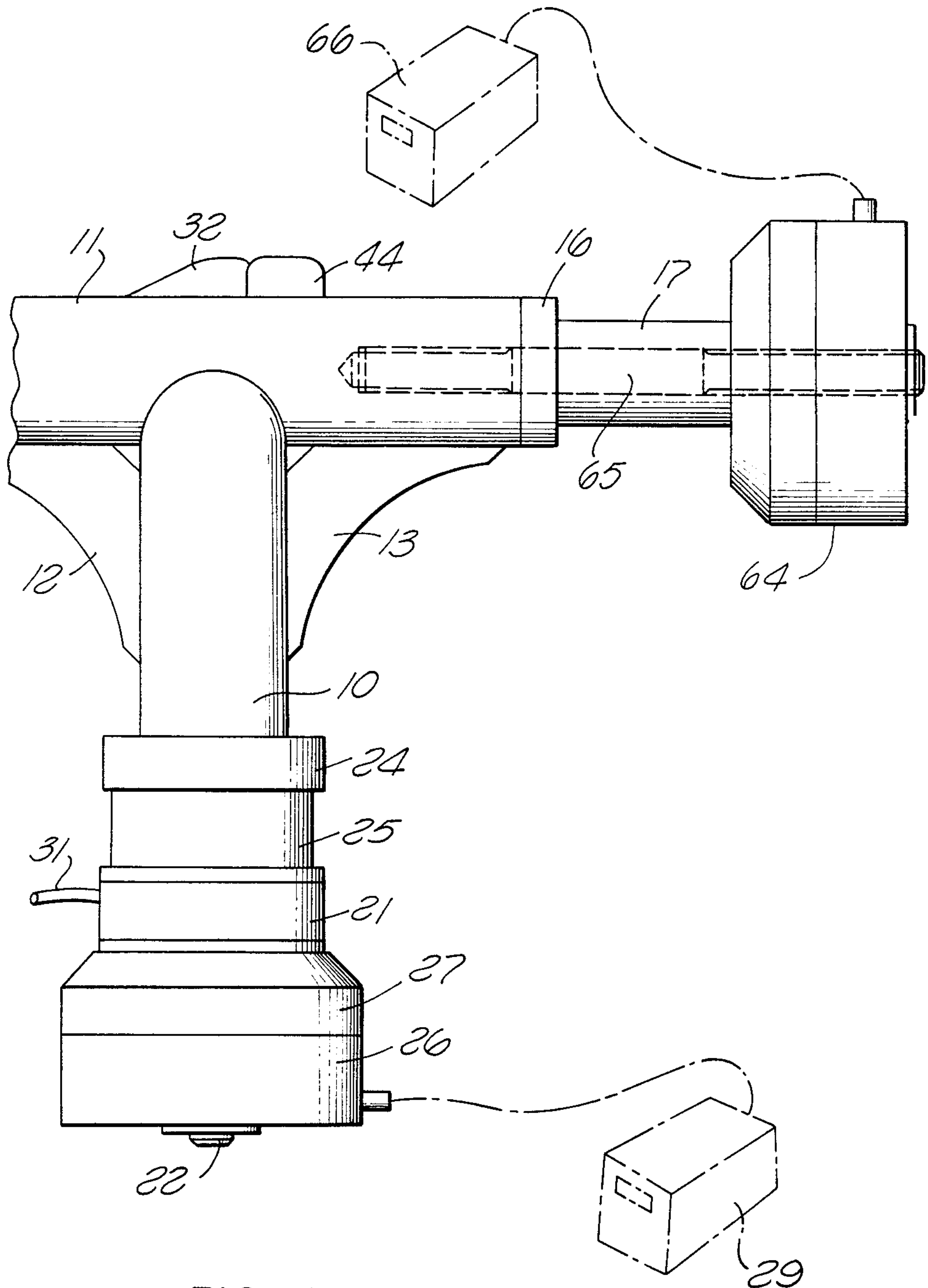

FIG. 4

PORTABLE 90 DEGREE PROOF LOADING DEVICE

ORIGIN OF THE INVENTION

The invention described herein was made in the performance of work under a NASA contract and is subject to the provisions of Section 305 of the National Aeronautics and Space Act of 1958, Public Law 85-568 (72) Stat. 435; 42 U.S.C. 2457).

DESCRIPTION

1. Technical Field

The invention relates generally to localized test load application, and more specifically to apparatus for bidirectional force application to a bearing or the like with respect to its mounting or staking in a bore through a housing or bulkhead, particularly in limited access situations.

2. Background Art

Wherever a bearing or similar part is installed into a bore or opening in a housing or bulkhead, the question arises as to the thrust resistance of this installation. In most mass produced assemblies, such as automotive vehicles, for example, design criteria are relied upon to ensure the integrity of the installation and individual proof loading is not employed. Such reliance is justified where failures or degradations in bearing performance only result in the need for repair or replacement.

In some situations, an extremely high degree of operational reliability is necessary, such as in aircraft or space vehicles. In those instances, degradation or outright failure of a bearing or its mounting can have serious consequences. In spacecraft especially, the individual proof loading of some bearings is essential. Also, this proof loading often must be accomplished as near to a final assembly situation as possible. Accordingly, tight access situations are likely to be encountered such that a test device which is substantially elongated cannot clear obstructions or be fitted into limited recesses adjacent to bearings to be proved.

It is therefore a requirement that a proof loading device of the type to which the invention applies be as small as possible, as short overall in the direction of load force application, and that load cells, hydraulic cylinder drive, etc., be as removed from the immediate vicinity of the bearing to be proofed as possible.

In the prior art, the application of proof testing forces to fasteners is described in U.S. Pat. No. 3,563,087 (L. J. Brunelle et al.). In that reference a hydraulically induced (pulling only) force, measured by a conventional fluid pressure gauge, is applied. The Brunelle apparatus is not for bidirectional test force application and therefore is not adapted to such applications as testing of the integrity of bearing staking, the latter being a prime function of the present invention. The force application measurement technique in Brunelle is not sufficiently accurate for critical bearing staking proof testing since the static friction of the hydraulic piston used will subtract from the force indicated by the gauge. Moreover, the repeatability of the actual force applied is likely to be inadequate because of this same static piston friction characteristic.

A device described by Shutt in U.S. Pat. No. 4,030,353 gives the superficial impression of a right angle device possibly adapted to provide applicant's functions, however upon closer analysis proves to be a cable winch arrangement such as might be used in helicopter rescue operations, Shutt's actual teachings relate to limiting the torque or force applied to position the boom of the device. Thus the Shutt apparatus does not relate to the same art as the present invention.

In U.S. Pat. No. 3,693,418 (Kaspareck), a purely mechanical force applicator is suggestive of the familiar hand operated center punch. In Kaspareck, the force applied (compression only) is a function of mechanical parameters, principally the spring constant of a compression spring. Variable internal static friction would inherently cause variation of the force applied before reset and no independent force measuring structure is provided. Apparatus of the Kaspareck type would not be suitable for the aircraft and spacecraft bearing staking proof loading application contemplated for the present invention.

U.S. Pat. No. 3,485,092 (Benner) shows a force control arrangement adapted for a motor and lead-screw driver table apparatus such as in a lathe or other similar power tool. The Benner invention appears to limit the force applied to an advancing tool, held by a moving chuck for example. Such apparatus as shown by Benner is clearly not adapted to the purpose of the present invention.

The manner in which the invention solves the problem of proof loading of installed bearings and the like by applying a unique 90° thrust conversion principle along with a unique structural arrangement for insuring the measured repeatability of the applied force will be evident as this description proceeds.

DISCLOSURE OF THE INVENTION

The invention comprises portable tester apparatus which can be hand held. The tester comprises a rigid, tee-shaped, generally tubular housing in which a first thrust rod is mounted with minimum static frictional resistance, in the column of the tee-shaped housing assembly for transmission of a pulling force generated by a hydraulic cylinder and measured by a conventional loade cell. The first thrust rod is essentially a pull rod and its force is transferred to a second thrust rod (horizontal shaft) in the cross-arm housing portion. This second thrust rod, like the first rod, is mounted in minimum friction bearings or ball bushings.

The pulling force exerted by the first rod is generated by a hydraulic cylinder and measured by a load cell, preferably of the strain guage type. An actuator plate (cam) is attached to the first thrust rod adjacent to the intersection of the column and cross-arm portions of the housing. The cam has a sloping ramp exerting a compressive force on a cam follower wheel attached to the second thrust rod (horizontal shaft) which results in a 90° axial force (with respect to the axis of the first thrust rod) being transmitted to the second rod.

At an end of the cross-arm housing portion, the second thrust rod projects from the housing and alternative load inserts (interface parts) provide for application of the proof load to the bearing or bushing in either direction with respect to the bulkhead in which the said bearing or bushing is installed (staked). Thus, a pinching force between the end of the aforementioned cross-arm housing portion can stress the bearing installation in either direction.

The 90° configuration of the apparatus of the invention is such that the hydraulic cylinder and load cell are removed from the structure associated with the second thrust rod and cross-arm housing portion, thereby facili-

tating closer quarter use of the test (proof load) apparatus than possible if those elements were aligned axially in an elongated configuration.

The details of a typical embodiment which appears, at this time, to comprise the best mode of implementation for the invention, are hereinafter set forth.

BRIEF DESCRIPTION OF THE DRAWINGS

The details of the invention will be described in connection with accompanying drawings in which FIG. 1 is a partially axially sectioned view of an assembly of the apparatus of the invention; FIG. 2 is a top view of FIG. 1 also showing the application of the invention in a limited access situation; FIGS. 3*a* and 3*b* show detailed interface parts and their relationship to the bearing or bushing to be subjected to proof loading, for the two alternative directins of proof load as indicated; and FIG. 4 shows the arrangement of apparatus for calibration and proving of the repeatability of output force versus input force in the device.

BEST MODE FOR CARRYING OUT THE INVENTION

Referring now to FIG. **1**, the arrangement of the parts of the Proof Loading Device will be seen. The generally tubular tee-shaped housing has a column housing portion **10** and a cross-arm housing portion **11**. These housing portions **10** and **11** are rigidly joined and braced by gussest **12** and **13**, as by a welding operation at lines of contact such as **14** and **15**, typically.

To the right end of tubular housing portion **11** (as pictured in FIG. **1**), a disk-shaped piece **16** is fixed and a further tubular housing portion **17** is fixed to and extends from the disk-shaped piece **16** as illustrated.

A first thrust rod (internal shaft) **18** is contained within the housing column portion **10** and is free to translate axially with minimal friction within a support bearing **19**. The support bearing **19** is normally of the type having a plurality of bearing balls extending both circumferentially and axially (ball bushing), and provides the desired support with minimum frictional resistance to axial movement of the first thrust rod **18**. The support bearing **19** has an outer race **20**, which is firmly fitted into the internal bore of the column housing portion **10**. Acutally, in operation, the first thrust rod **18** is pulled downward by a hydraulic cylinder **21**, but very little movement is actually caused, the transmission of the proof loading force being substantially a static situation. Movement of the first thrust rod **18** will later be seen to be indicative of failure of the bearing being proof loaded or "give" in the staking thereof. Accordingly, minimal static friction is most important, as will be understood more clearly hereinafter.

The downward thrust of the first thrust rod **18** is transmitted through a threaded spindle **22** which engages internal threads in an axial bore **33** within the first thrust rod **18**. Similarly, the threaded spindle **22** is continuous through central clearance bores in spacers **24** and **25** and firmly into the base **26** of a load cell **27** via the threaded engagement **28**. The threaded base **26** is bolted as shown and thus acts as an anvil placing the active portion of load cell **27** under compression (in operation) between housing portion **10** and this load cell threaded base **26**. The aforementioned load cell **27** is an electrically responsive transducer of the strain gauge type, and is a commercially available part (catalog No. 500, obtainable from Interface, Inc., 7401 Butherns, Scottsdale, Ariz.).

The magnitude of the compressive force exerted against load cell **27** is measured by an instrument **29** (measuring load cell resistance, for example). A suitable instrument, properly scaled to read a force in kilograms or pounds directly on a digital read-out may include Digital Read-Out #7500 coupled with a Transducer Switching Unit TSU-5, both as manufactured by Interface, Inc., 7401 Butherns, Socttsdale, Ariz.

Of course, other well-known instrumentation could be substituted once it is understood that the compressive force extant between the lower end of threaded spindle **22** and the lower end of the column housing portion **10** is that which is to measured.

The hydraulic cylinder **21** having a fluid port **31** responds by expanding axially (along a vertical line in FIG. **1**) in response to hydraulic fluid under pressure introduced externally via port **31**, and this will be seen to produce the downward thrust of the threaded spindle and compression loading of the load cell **27**. The hydraulic cylinder **21** is in fact a hydraulic jack, available under part No. RWH-120 from Ereopac, Inc., division of Applied power, Inc., Butler, Wis.

A cam **32** will be seen to be pinned to a flat **33** in the first thrust rod **18** (actually the flat **33** being one surface produced by bifurcation of rod **18**), by pin **34** which is pressed into a lateral bore formed in the first thrust rod **18**. In operation, cam **32** is urged in a downward direction (as viewed on FIG. **1**) so that its cam surface **35** exerts a force, which resolves into a downward component and a leftward component on a cam follower wheel **36**.

Cam follower wheel **36** is preferably a standard ball bearing with its inner race press fitted onto a pin **37** which is firmly attached to a horizontal (second thrust) shaft **38**. It will be seen more clearly from FIG. **2** that the cam follower wheel **36** is actually within slot **53**. Accordingly, minimal frictional resistance to rotation of cam follower wheel **36** is encountered.

A pair of bearings **39** and **40**, identified by the manufacturer as Ball Bushings—Super 16, (of the same type as the support bearing **19**) effectively restricts any but axially sliding motion of horizontal shaft **38**, that motion being resisted only by minimal friction in bearings **39** and **40**. These bearings, as well as support bearing **19**, are available from Thompson Industries, Inc., Manhasset, N.Y. The bearings **39** and **40** are firmly fitted (outer races press-fitted into the inside bore of the tubular cross-arm housing portion **11**).

The mounting of cam **32** on pin **34** need not completely restrict the cam **32** from rotational freedom of itself (about pin **34**), since a second roller or wheel **42** (likewise preferably itself a ball bearing such as, NR-1606 from Boston Gear, Quincy, Mass.) has its inner race pressed onto a pin **43**. Pin **43** is in turn firmly attached to boss **44**, which is in turn a part of or firmly mounted on the outside surface of cross-arm housing portion **11**. Actually, pin **43** is supported between boss **44** and boss **54** as will be seen from FIG. **2**.

From the foregoing, it will be realized that, in operation, cam **32** is restricted from any but downward motion (as viewed on FIG. **1**), this downward motion or thrust being effectively and exclusively translated to a leftward thrust applied to horizontal shaft **38** with minimum static friction. Horizontal shaft **38** is free to project from the open end **41** of cross-arm housing portion **11**.

It could be said that the cam follower wheel **36** and the second wheel **42** prevent lateral play of cam **32**, keeping the cam surface **35** always in contact with cam

follower wheel **36** during operation. Moreover, it should be noted that cam **32** clears the surfaces of slot **53** and touches only wheels **36** and **42** during operation.

Spindle **45** attaches to horizontal shaft **38**, as an extension thereof, by means of a threaded engagement **46** within an axial bore in horizontal shaft **38** as illustrated.

The support provided by bearings **39** and **40** is such that only minimum clearance of spindle **45** such as shown by **48** and **49** is necessary.

It will be realized at this point that the horizontal shaft **38** and its extension spindle **45** can only be caused to exert a compression force, between the end cap assembly **50** and the tubular housing portion **17**. The interface structure which applies the test or proof loading to a bearing or other part under test will be described subsequently in connection with FIG. 3*a* and 3*b*.

It may occur to the reader that measurement of hydraulic pressure at fluid port **31** would also provide an indication of the applied pressure between end cap assembly **50** and the end of cross-arm housing portion **11**. While it is true that such a measurement, properly scaled, would indicate the applied pressure, the nature of hydraulic cylinders with their required tight sliding seals, is such that the repeatability of the net force as a function of hydraulic pressure is not sufficient for applications in which a proof load specification may set a repeatability tolerance of a relatively few pounds in a total force of several thousands of pounds.

Referring now to FIG. **2**, a top view of the apparatus of the invention shows a typical restricted access situation.

From FIGS. **1** and **2**, it will be noted that the cam **32** can be allowed to project through the top of cross-arm housing portion **11**. A structural part of an aircraft, spacecraft, etc., is represented at **51**. The structural part **51** actually contains a bore into which a bearing **52** has been fitted.

It will be noted from FIG. **2** that the horizontal shaft **38** (as well as cross-arm housing portion **11**) has a slot **53** through which the cam **32** can project. The axial length of this slot in horizontal shaft **38** is defined by dashed lines on FIG. **1**, but will be seen to be shorter through the wall of cross-arm housing portion **11**. The axial length of slot **53** in the cross-arm housing portion **11** is sufficient to accommodate the full dimension of the cam **32** in the axial direction of horizontal shaft **38**. The support for the second roller or wheel **42** and its pin **43** will be seen to be provided between the bosses **44** and **54**, both affixed to the outside surface of the cross-arm housing portion **11**. The pin **37**, which is anchored within horizonatl shaft **38** is also seen in FIG. **2**, as is cam follower wheel **36**.

Referring now to FIG. 3*a*, the outer race of the installed bearing (to be proof loaded is represented at **68** while the inner race is depicted at **55**. In this case the bearing outer race **68** may be simple press-fitted into a bore in structural part **51**, or it may be staked therein in the manner displayed in somewhat exaggerated form in FIG. 3*b*. A spindle **45** (necked down at its outer end) is an extension of horizontal shaft **38** and passes with clearance through the inner race **55** of the test bearing and a threaded end thereof engages threads in the cap **50** at **56**.

An interface part **57** of the general shape as depicted in FIG. 3*a* serves to abut the structural part **51** without contacting the bearing. Spindle **45** passes through the center bore of the interface part **57** with clearance as was the case with the bearing inner race **55**. A washer **58** serves to provide the appropriate surface interface between the bearing **52** and end cap assembly **50**. However, it will be realized that the surface of the end cap assembly **50** itself could make washer **58** unnecessary if the relative bearing and cap diameters were appropriate, i.e., if the outer bearing race **68** in FIG. 3*a* has a diameter relatively larger than that of end cap assembly **50**.

It will be understood from the description of FIG. 3*a* that the compression force between part **57** and the end cap assembly **50** exerts a net force on the bearing races **68** and **55** tending to push it to the left as viewed on FIG. 3*a*. If the installation of that bearing is not adequate to resist a prescribed test or proof force so applied, the applied force will be seen to decrease as indicated by instrument **29** (FIG. **1**) corresponding to a yielding of the position of the bearing for a given steady applied force.

Referring now to FIG. 3*b*, a different type of bearing, namely the single truncated ball **59** with or without bearing balls in shown. In this example, the abutting interface part **57** has been moved to the position shown against the end cap assembly **50**. Another interface part **60** designed with a central abutting surface has been placed against the end of tubular housing portion **17**. Thus, the same compressive force developed between end cap assembly **50** and tubular housing portion **17** now applies the test force in the opposite direction as compared to FIG. 3*a*, namely to the right of FIG. 3*b*. Also, the configuration of FIG. 3*b* will be seen to test the integrity of ball **59** within the staked race **61** as well as the staking of race **61** to structural part **51**. Thus, the race **61** is staked by rolled projections **62** and **63** over the chamfered surfaces of the bore in structural part **51** into which the bearing assembly is staked. It will be understood that the staking shown is somewhat exaggerated for clarity of description.

It will be clear from the foregoing description that various modifications to the specific structure are possible for the accommodation of bearings of various sizes and types, or for press-fit or staked bushings or the like.

Referring now to FIG. **4**, an unsectioned equivalent to FIG. **1** is presented, primarily to show the force calibration technique used to prove the repeatability and low static friction of the overall device. For that purpose, an additional load cell **64**, (as nearly identical to load cell **27** as possible) is placed at the end of and abutting tubular housing portion **17** in lieu of the interface parts illustrated in FIG. 3*a* and 3*b*. A temporary threaded shaft **65** engages the horizontal shaft **38** (within cross-arm housing portion **11**) at threaded engagement **46** in FIG. The threaded shaft **65** also has a second threaded end to engage the base of load cell **64** comparable to the threaded engagement **28** in base **26** of FIG. **1**. In this way, a second read-out on instrument **66** is available and, over a predetermined range of applied forces by hydraulic cylinder **21**, must read the same as instrument **29** within a prescribed tolerance. A larger than specified discrepancy between the readings of instruments **29** and **66** during calibration is indicative of excessive static friction within the device.

FIG. **4** also identifies various parts which are the same as described in FIG. **1** as will be obvious to the reader.

The arrangement of FIG. **4** is used only to confirm that the internal friction of the device is relatively low and therefore the readings of displays are normally

close and are repeatable, not as an operational arrangement.

Various modifications and variations will suggest themselves to those of skill in this art, for example, in some cases it may be disirable to avoid loading the inner race of a bearing such as the inner race **55** (FIG. 3*a*, and accordingly, washer **58** can be counterbored or recessed on its surface facing inner bearing race **55**. In the opposite loading sense, the interface surface of interface part **60**, as in FIG. 3*b*, can be similarly counterbored or recessed such that it contacts only the staked race **61**.

Bearings are sometimes bonded to the bore in which they are fitted (for example, outer race **68** may be bonded to the bore in structural part **51** in FIG. 3*a*), and the proof loading then tests the integrity of this bond.

Other modifications within the spirit of the invention will occur to the skilled reader once the concepts of the invention are understood. For still another example, accurately machined sleeve bearings could be substituted for bearings **19**, **39** and **40**, the main criterion for those bearings being very low friction.

Suitable materials are readily selected through exercise of ordinary design skill.

We claim:

1. A device for proof loading of bearings and the like, comprising: a generally tee-shaped tubular housing having column and cross-arm portions, externally firmly attached to each other; a first thrust rod within said housing column portion and low friction support means associated therewith, said first thrust rod and low friction support means being positioned and arranged so as to permit low frictional, longitudinal translation of said first rod; a second thrust rod within said housing cross-arm portion and low friction support means associated therewith, said second thrust rod and low friction support means being positioned and arranged so as to permit low frictional, longitudinal translation of said second rod, said second rod projecting from an end of said cross-arm housing portion; a cam attached to one end of said first thrust rod substantially at the junction of said column and cross-arm housing portions and a cam follower attached to said second thrust rod, said cam having an angled surface in contact with said cam follower such that a pulling force applied to a second end of said first rod produces a pulling force tending to draw said thrust rod into said cross-arm housing portion; fluid operated means for applying said pulling force to said first rod and load cell and display means for measuring and displaying the magnitude of said first rod pulling force; and a pair of interchangeable interface parts cooperating with said second thrust rod with one of said parts being mounted on the projecting end of said second thrust rod, one of which has a force application surface having a greater diameter than the diameter of the other part having a force application surface.

2. A device according to claim **1** in which the angle between said column and cross-arm housing portions and therefore between said first and second thrust rods is substantially a right angle.

3. A device according to claim **2** in which said first and second thrust rod low friction support means comprise, respectively, a first thrust bearing within said column housing portion and second and third thrust bearings within said cross-arm housing portion, one of said second and third thrust bearings being placed on each side of said cam.

4. A device according to claim **3** in which said cam follower is a first roller rotatably mounted to said second thrust rod about a low friction bearing.

5. A device according to claim **4** in which a second roller is rotatably mounted to said cross-arm housing portion and bears upon a surface of said cam substantially opposite to said angled surface of said cam.

6. A device according to claim **5** in which said cam angled surface is substantially a 45° surface with respect to said first thrust rod.

7. A device according to claim **6** wherein said interface parts have a central bore and in which said portion of said second rod projecting from an end of said cross-arm housing portion outside of said cross-arm housing portion is a diameter to pass with clearance through said central bore of said interface parts except said outer interface part.

8. A device according to claim **2** in which said cam angled surface is substantailly a 45° surface with respect to said first thrust rod.

9. A device according to claim **1** in which said first and second thrust rod low firction support means comprise, respectively, a first thrust bearing within said column housing portion and second and third thrust bearings within said cross-arm housing portion, one of said second and third thrust bearings being placed on each said of said cam.

10. A device according to claim **1** in which said cam follower is a first roller rotatably mounted to said second thrust rod about a low friction bearing.

11. A device according to claim **10** further including a second roller rotatably mounted to said cross-arm housing portion and bearing upon a surface of said cam sutstantially opposite to said angled surface of said cam.

12. A device according to claim **1** in which said fluid operated means for applying said first rod pulling force is a hydraulic cylinder.

13. A device according to claim **1** wherein said interface parts have a central bore and in which said portion of said second rod projecting from an end of said cross-arm housint portion outside of said cross-arm housing portion is of a diameter to pass with clearance through said central bore of said interface parts except said outer interface part.

14. A device according to claim **1** in which said cross-arm housing portion includes a slot aligned with said cam, and said cam projects through said slot at least partly outside said cross-arm housing portion to minimize the overall size of said cross-arm housing portion.

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